

VIII. *Experiments and Observations in Electricity.*

By Mr. William Henly, F. R. S.

P A R T I.

*Remarks on the effects of lamp-black and tar, or lamp-black and oil, as protectors of bodies from the stroke of lightning; with similar effects produced by experiments in the artificial electricity.*

Read, Jan. 16 and 23,  
1777.

**D**R. LEWIS, in his *Philosophical Commerce of Arts*, p. 364. mentions a remarkable instance of the effect of a coating of lamp-black and tar, in preserving those parts of the mast of a ship, which were covered with it, from damage by a stroke of lightning which shivered the other, that is, the uncoated parts of it, in a very extraordinary manner. The account is recited at large in vol. XLVIII. of the *Philosophical Transactions*. Captain NAIRNE, in his *Remarks on the Effects of Lightning*, on the masts of several vessels which were struck in the Bay of Quebec<sup>(a)</sup>, mentions, in his letters to some friends in London, no less than five instances, where the lightning passing

(a) His own ship, the *Generous Friends*, was twice preserved there by his conductor.

over

over those parts of the masts of the ships which were covered with lamp-black and tar, or painted with lamp-black and oil, without the least injury, shivered the uncoated parts (tearing out splinters five or six feet in length, and six or eight inches deep) in such a manner as to render the masts entirely useless. A very curious instance of this kind hath lately been communicated to me by a learned and ingenious member of the Royal Society, from whom I received the account which I shall here insert *verbatim*,

“ On the first of April, 1776, being on board a brig  
 “ in the latitude  $34^{\circ}$  N. our vessel was struck with light-  
 “ ning, which disabled our fore-mast. Upon getting the  
 “ whole of the top-masts down upon the deck, I ob-  
 “ served the following particulars, with regard to the  
 “ course and effects of the electrical matter. The light-  
 “ ning had first struck the pinnacle of the fore-top-gal-  
 “ lant-mast (on which, at that time, there happened to  
 “ be no iron spindle, as usual) which it just split slightly  
 “ for about two feet and a half, where it was painted  
 “ with lamp-black and oil (I could not, however, ascer-  
 “ tain whether this part of the mast had been newly  
 “ split or not: it might have been first occasioned by  
 “ driving in the iron spindle, whereon a vane is usually  
 “ placed; for there was a hole where such a spindle had  
 “ been

“ been fixed) and then the lightning immediately shi-  
“ vered the rest of that mast as far as it was greased, till  
“ it met the bottom of that and the top of the top-mast,  
“ which had likewise been coated over with lamp-black  
“ and oil, on an old coat of tar. Over these it glanced,  
“ without any perceptible effect, till it reached that part  
“ of the top-mast which was also greased; this part it shi-  
“ vered, splitting off large splinters which were thrown  
“ on the deck. The lower part of the fore-mast being  
“ tarred, the lightning slid over it for about nine  
“ feet, without the least mark of violence; then darted  
“ into the fore-mast, where it was greased; rived it ter-  
“ ribly, tearing off splinters as large as a man’s arm, and  
“ four or five feet long, all the way down. It continued  
“ this course till it again met a coat of tar, which was  
“ laid on the mast for more than five feet above the  
“ deck; here its effects on the mast disappeared, and its  
“ course seemed to be divided different ways by two at-  
“ tractive bodies of iron; one, in a cleet fastened to the  
“ fore-mast, about ten inches below the top of the last  
“ mentioned coat of tar, by two large spike-nails: this  
“ cleet with the nails was entirely struck off; the light-  
“ ning then tore the canvas coating round the foot of  
“ the mast (about a yard below the cleet) without any  
“ other hurt to the mast itself; and from thence was  
“ attracted.

“ attracted by a large anchor lying in a horizontal position on the deck, about two feet from the mast. All this part of the electrical matter seems to have been then discharged by the different conductors of the two flukes and the main shank of the anchor, without any other visible effect than breaking a piece out of a large iron pot, standing in an immediate direction to one of the flukes, and about ten inches distant. The other division of the electrical matter darted from the mast to the belfry, about fifteen inches distant, tore off two cleets fastened to it by large iron nails; then descended to the large iron hinges which hold the palls or stops (joined to the belfry-posts) of the windlafs, where, after tearing off a small nail or two, it totally disappeared. The belfry which was painted was much split, but not broke to pieces. The most remarkable part of this accident, and for which the whole relation is given, is, the effect of the tar and lamp-black and oil as repellents of the electrical matter; for in four instances, 1<sup>st</sup>, at the head of the fore-top-gallant-mast; 2<sup>dly</sup>, at the bottom of that and head of the top-mast; 3<sup>dly</sup>, at the bottom of the top-mast and head of the fore-mast; and 4<sup>thly</sup>, at the bottom of the fore-mast; the lightning had glanced over all those parts without doing the least damage, and had regularly darted into,

“ and

“ and shivered all the intermediate parts of those masts,  
“ where they were covered with grease. This appears  
“ so extraordinary to me, that I thought proper to take a  
“ note of it upon the spot, in order to occasion the making  
“ of some philosophical inquiries and experiments on  
“ the subject by those more capable of accounting for it  
“ than myself: and for that reason the above relation  
“ may be depended on as just and true, after a repeated  
“ and critical examination of the several parts of the  
“ masts which I have described. W. D.”

In consequence of this relation, and the hint which concludes it, I have been induced to make the following experiments. 1st, A glass tube, eight inches long, with a bore or cavity of about a quarter of an inch diameter, being filled pretty closely with lamp-black, and each end stopped with a bullet, the stem of which just entered, and was cemented in the cavity of the tube, conducted the charge of a jar containing three square feet of coated surface instantaneously, but with scarce any explosion. 2dly, Such a tube being filled with a mixture of lamp-black and oil (as used by the painters) entirely failed to conduct the shock. 3dly, The outer surface of such a tube being painted with lamp-black and oil, and excited with dry warm flannel, acted (the tube being also dry and warm) as a very strong negative electric. 4thly, A piece

of polished plate glass being introduced into the circuit, the ends of the wires which composed the circuit were laid at about an inch and an half from each other upon the surface of the glass, when the jar above-mentioned being discharged, the polish of the glass was always torn off in an irregular and deep line, extending from one wire to the other; but if a piece of glass painted with lamp-black and oil were thus introduced into the circuit, and the discharge made as before, not the smallest trace of the electricity could ever be perceived on its surface. 5thly, If instead of the glass, a slip of writing-paper was introduced into the circuit, it was torn in pieces by the explosion, much of it flying about the room in the form of fine flue or down. 6thly, A slip of the same paper, painted with lamp-black and oil, received not the least injury, nor shewed the smallest trace of the electricity upon its surface; but the common oiled paper, without lamp-black, was torn considerably, though not so much as the paper unoiled<sup>(b)</sup>. When the charge of the jar above-mentioned is made to pass between the surface

(b) Mr. CAVALLLO, who hath since repeated these experiments, finds, that if the paper be very thinly painted with the lamp-black and oil, it will be torn by the explosion; but having tried a piece of the same that I had used in my experiments, he was not able to make the least impression on it. Lamp-black and tar therefore, on account of the greater tenacity of the latter, and its being equally a non-conductor, seems to be the most proper for the purpose.

of

of thick plate glass, and that of a cylinder of ivory three-quarters of an inch diameter, pressed by a weight of about six or eight ounces Troy; the glass is always shivered into very small fragments, and part of it is sometimes reduced to an impalpable powder. But 7thly, If the plate of glass be covered with a slip of writing-paper, painted with lamp-black and oil, or with a slip of oiled silk (such as is frequently used for garments) the charge passes over these substances without leaving the smallest trace on either of them, though the glass under them be broken by the blow of the explosion.

From these experiments, and the observations above recited, I think the following corollaries may be deduced. 1st, That a charge of electricity, or a stroke of lightning, which is the same thing, passes, in many cases, upon the surface of bodies, in a much larger proportion than through the interior substance of them, as appears by the masts of ships, coated with lamp-black, &c.<sup>(c)</sup>, and by the experiment above recited, with the cylinder of ivory and the glass &c.; for in this experiment, the charge being resisted by the ivory (which however is sometimes split by the explosion) forces a passage between that and the glass, and being there confined by heavy weights, exerts

(c) See a curious instance of this kind in M. ADANSON'S *Voyage to Senegal*, p. 239.

its expansive power in such manner as to reduce to the smallest fragments the plate of glass then exposed to its violent operation. 2dly, This violent effort of the electricity produces not the least effect upon the surface of the slip of paper painted with lamp-black and oil, or upon a slip of oiled silk, placed in the same situation. 3dly, May not therefore a coating of lamp-black and tar, or lamp-black and oil, be in some cases usefully applied on flight buildings of wood, &c. to preserve them from damage by lightning, as well as to prevent those large cracks and rents (the usual effect of the heat of the sun) from being made in them? 4thly, As the effect of the lightning on the masts of ships has been in so many instances prevented by a coating of lamp-black and tar, or lamp-black and oil, it seems probable, that a safe and fixed conductor might be applied to them in a very cheap and convenient manner, as follows; *viz.* let all those parts of the mast which are usually greased, be provided with plates of metal three inches broad, which plates might extend a few inches upon the other parts of the mast which are coated with lamp-black and tar, or lamp-black and oil; and thus by the conductor of metal, and the protector of lamp-black and tar, placed alternately and extending the whole length of the mast, it would probably be preserved from damage by lightning. A  
metallic



metallic communication might be made from the mast to the water in the manner I have before mentioned, in Phil. Trans. vol. LXIV. p. 412. This method of making conductors to ships, from its simplicity and practicability, I had some thoughts of recommending to my acquaintance in the marine department; but there is one objection to it, which I think a very material one, and shall therefore state it in its full force: it is this; the lamp-black and tar, or lamp-black and oil, though they protect, by their property of repelling the electric matter, those parts of the mast which are coated with them, yet being perfect non-conductors, those things or persons which might happen to stand in their vicinity (as in the tops, &c.) would be in danger of a severe stroke, perhaps destruction, by the lightning. How far the other oil colours, *viz.* those prepared from minerals and metals, may answer these purposes, may perhaps deserve enquiry, and the more so, as the experiments are not difficult to make. The belfry-poets painted with white lead, mentioned in the letter above recited, were much shivered. 5thly, As oiled silk seems to be so good a security against the effects of a charge of electricity, may not garments, *viz.* cloaks and hats, covered with that substance, contribute in some measure to protect the wearers (if overtaken by a storm) from a stroke of lightning? particularly, if the precau-

tions be properly attended to, which I have before recommended from Dr. WINTHROP, in Phil. Transf. vol. LXIV. p. 151.

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## P A R T II.

*On the electricity of chocolate: and the restoration of that property to it, when lost, by melting it together with a small quantity of olive-oil.*

HAVING been informed by my ingenious friend Mr. GEORGE ADAMS, philosophical instrument-maker to his majesty, that Mr. SANDERS, an eminent manufacturer of chocolate, had frequently observed a very vivid light flashing upon its surface, when cooling in the tin pans in which it is received from the mill; particularly in clear, frosty evenings, when it would also strongly attract light substances, such as small particles of dust, bits of paper, straw, thread, &c.<sup>(d)</sup>; I was very desirous to ascertain, if I could, the cause of these phenomena. For this purpose I waited on Mr. SANDERS, in company with Mr. ADAMS, and made the following experiments. 1st, A large cake

(d) The wax-chandlers also, in forming their sticks, &c. of wax, are frequently spectators of these effects of electric attraction.

of chocolate being turned out of the tin pan, in which it had been set to cool; I presented towards it Mr. CANTON's electrometer, and observed that, at six inches distance, the balls began to diverge; and when they came within two inches of the chocolate (being suspended over it) their divergence was full an inch and an half, and upon examining their electricity, I found the chocolate to be in a *plus* or positive state. 2dly, Having separated another large cake from the pan, I touched it repeatedly with the knob of a small phial, properly prepared for the Leyden experiment; then bringing that knob gently toward one of my knuckles, I saw a spark between them, and had a small sensation in my knuckle. 3dly, Having separated another cake of chocolate from the tin pan which contained it, I touched the cake repeatedly with the brass ball on the neck of my Leyden *vacuum*, or analysis of the Leyden bottle<sup>(e)</sup>, and instantly perceived a most beautiful and large pencil of rays darting from the wire, and spreading themselves through the bulb towards the coated part of the bottle. 4thly, Changing the position of the bottle, I presented the coated bulb towards the chocolate, and then perceived (as I expected) a small luminous spark upon the point of the wire in the neck of the bottle; completely proving the electrical quality of the

(e) Described in Phil. Transf. vol. LXIV. p. 400.

chocolate, and ascertaining its direction in the experiments.

Before I had an opportunity of making this complete investigation, I had separated a piece of chocolate from the tin pan in which it had been cooled, and accidentally left, for some months, under an open counter in a shop, exposed to dust, damp air &c.; notwithstanding which, on its separation from the pan, it attracted a thread of trial at a quarter of an inch distance. I then took a quarter of a pound of chocolate, and having melted it in an iron ladle, poured it into a tin pan, and the next day (it being perfectly cooled) separated it from the pan, and found it strongly electrified *plus*; but as the electricity was soon lost by handling (owing, I suppose, to the large quantity of conducting matter contained in it) I melted it again, but produced no electricity; which I imputed to the chocolate having become very dry and powdery. I therefore melted it a third time, adding a little oil of turpentine; but this trial also (perhaps from the evaporation of the spirit) failed. I then melted it the fourth time, and added a small quantity of olive-oil, sufficient as I imagined to reduce it again to its original consistence, and having cooled it in the tin pan as before, I found on removing it, that its electricity was completely restored. The large proportion of phlogiston in oil is well known; and as the addition of oil to the chocolate completely

completely restored its electricity when lost, is not this an indication of a great affinity at least between phlogiston and the electric fluid, if indeed they be not the same thing<sup>(f)</sup>? Further, as electricity is produced in the chocolate by heat and friction, and manifested by its usual phenomena in the cooling of that substance, *query*, may not electricity be produced from the other oily nuts, kernels, or seeds (particularly those of the torrid zone) treated in the same manner?

However, as the electric matter is resident in, and may be disengaged from, all the substances we are acquainted with; as the air is at all times replete with it; as its operation is so secret, so rapid, and at times so tremendous; as it is so easily excited or put in action by friction, by heating and cooling, and perhaps by means we are totally unacquainted with; I think we may safely conclude, that electricity, as it is one of the most powerful, is also one of the most important, agents in nature. Many useful discoveries have been made respecting the action, influence, and effects of this subtle fluid; but certainly much remains to be done, and the field for future labourers seems daily to enlarge. Indeed, notwithstanding the number of discoveries in electricity this age may justly boast of, I cannot but be of opinion (which I men-

(f) A thick scum from the surface of some linseed-oil exposed to the air, and thoroughly dried, became a very strong negative electric.

tion as an incitement to the study) that, compared with the facts still undiscovered in that branch of philosophy, they bear but a very small proportion.

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### P A R T III.

*Observations on some new and singular phenomena in excited and charged glass; with experiments made in consequence of these phenomena, further illustrating the Franklinian theory of the Leyden bottle; and a description of the apparatus constructed for that purpose by Mr. HENLY.*

HAVING carefully repeated the experiments with the two coated plates of looking-glass, mentioned in my paper on Mr. VOLTA's machine, and finding with Mr. LANE, that they exactly agreed with the account given by Mr. SYMMER and Mr. EFLES, I was desirous to be satisfied whether glasses of a different thickness would be differently affected in the experiment. For this purpose I tried two large squares of crown or window-glass, and found them to charge and discharge exactly as the looking-glass plates had done; but on trying the experiment with two plates of Nuremburg glass, commonly called Dutch plates, I was not a little surprised to find that each  
of

of the plates, when separated after charging, had a positive and a negative surface; and that having replaced them, and made the discharge as in the Leyden experiment, the electricity of all the surfaces was changed, though it appeared to be very strong, and continued to give repeated flashes of light, when the plates were alternately closed, touched, and separated, as the looking-glass plates above mentioned. If a clean dry uncoated plate of looking-glass was placed between the coated plates, either of looking-glass or crown-glass, before they were charged; that uncoated plate was always found, upon separating them after charging, to be electrified negatively on both its surfaces; but if it was put between the Dutch plates, it acquired, like them, a positive and a negative electricity. As this phenomenon was not satisfactorily accounted for, it occasioned much conversation with respect to Dr. FRANKLIN's theory of the Leyden bottle, which I had myself (as I imagined) satisfactorily explained and even demonstrated. I was, however, soon convinced, that that theory is not so generally received as I imagined; for I met with a number of gentlemen who not only doubted, but seemed absolutely to deny it. This induced me to make some further experiments, in order (if I could) more fully to illustrate that theory, and to put the matter out of doubt. For

this purpose a pretty large jar was coated and furnished as in fig. 1. A is the jar; BB the tin-foil coating; c a tin-stand which supports the jar; D a socket of metal which supports a rod of glass E; F a curved wire or plate of metal with points, not very sharp; this wire or plate of metal is fastened to the end of a brass rod G, which rod is moveable at pleasure in a spring tube H, that tube being fixed by a socket upon the top of the glass rod E. The charging wire of the jar communicates with both parts of the inside coating of the jar by horizontal wires (the ends of which are bent a little downwards) fixed at right angles to each other, in order to prevent shaking and rattling.

#### THE USE OF THE DOUBLE COATED JAR.

According to Dr. FRANKLIN's theory, the same quantity of the electric matter which is thrown upon one of the surfaces of glass in the operation of charging it, is at the same time repelled or driven out from the other surface, and thus one of the surfaces becomes charged *plus*, the other *minus*; and that this is really the case is, I think, satisfactorily proved by this contrivance. For example, place the jar as usual, with the knob in contact with the prime conductor; then work the machine, and the apparatus being perfectly dry and in good order, a small luminous spark will appear upon the upper point of the wire F (a plain indication that the point is then receiving electricity



electricity from the upper ring of coating on the outside of the jar) and a fine stream or pencil of rays will at the same time fly off, beautifully diverging from the lower point of the wire F upon the bottom ring of coating on the jar. When these appearances cease, which they will as soon as the jar becomes charged, let a pointed wire be presented towards the prime conductor; this will soon discharge the jar silently, during which the lower point of the wire F will be illumined with the small spark, while the upper point of the wire will throw off a fine pencil of rays, diverging towards the upper ring of coating, to which it stands contiguous, as upon Dr. FRANKLIN'S hypothesis it ought to do. A wire of the same form as that marked F may be inserted on a small electric stand, fitted by a proper base to the bottom of the jar on the inside; this will shew the appearances when the jar is charged negatively.

The same experiment may be very conveniently made with a large pane of crown glass<sup>(g)</sup>, coated in two places at a proper distance from each other (fig. 2.) leaving a sufficient quantity of glass uncovered quite round the two coatings. This coated plate of glass should be fixed in a frame, and mounted upon a proper electric stand. Another stand of glass or sealing wax should be provided,

(g) Mine is eighteen inches by fourteen inches.

to support a wire or piece of metal placed horizontally, and curved so as to bring the ends of it, which should have blunt points, within half an inch distance of the two tin-foil coatings on one of the surfaces of the glass. On the opposite side of the glass, two wires, bluntly pointed, are also to be employed; one of these is to communicate with the prime conductor, and to throw off the electricity from thence upon one of the coatings of tin-foil placed contiguous to it; the other wire is to communicate with the earth, standing in a perpendicular direction, with the point bent towards and reaching within half an inch of the other coating of tin-foil (on the same surface of the glass) to receive the electricity thrown off by that coating, while the opposite side is charging.

#### EXPERIMENT.

The apparatus being perfectly dry (the uncoated part of the glass and the frame, &c. should be varnished), clean, and in good order; the plate of glass should be so fixed, that each of the four coatings of tin-foil may come within half an inch of the point of the wire opposed to it. The apparatus being thus placed, if a powerful machine be worked in a dark room, the electricity will be seen to issue from the point of the wire in contact with the prime conductor upon one of the tin-foil coatings A  
(fig.

(fig. 3.) charging it positively. The coating B (fig. 3.) on the other side of the glass throwing off, at the same time, an equal quantity of the electric matter, (visible in the form of a small luminous spark upon the point of the insulated wire F) is thus left in a negative state. The electricity passing along the insulated wire, flies off from the other point of it in a pencil of rays, diverging upon the tin-foil coating C (fig. 2.) on the same side of the glass, charging it positively; while the opposite coating D (fig. 3.) throws off its electricity, which is received in a small spark upon the point of the wire (G) opposed to it, and communicating with the earth. Thus, by the same operation of the cylinder, may a positive and a negative charge of electricity be obtained at the same time upon each surface of the glass; and by applying two curved discharging rods (which should have glass handles) at the same instant, so as to come nearly into contact with the coatings upon each surface of the glass, the whole will be discharged together; or if a pointed wire be presented near to the prime conductor, they will all be discharged silently, and then the appearances on the points of the wires will all be reversed; that which was a brush or pencil of rays being now a small luminous spark, and that which was a luminous spark being a brush or pencil of rays. If the machine be very powerful, the  
rubber

rubber may be insulated, and a blunt pointed wire, communicating with the earth, may be placed within half an inch of it; this wire, while the plates are charging, will throw off a beautiful pencil of rays diverging upon the rubber, and thus compleatly exhibit the progress of the electricity through all the apparatus, from its exit out of the earth to its entrance into the earth again: and its return may be manifested by reversing all the appearances upon the points of the wires, in the operation of discharging the glass silently by a pointed wire presented toward the prime conductor, as above directed. Another very satisfactory method of demonstrating the truth of Dr. FRANKLIN's hypothesis is as follows. I take a bottle, containing about one hundred square inches of coated surface, properly prepared for the Leyden experiment, and holding it by the wire, I set the coating upon the prime conductor, and charge it negatively (fig. 6.); when charged (if not too dry) the upper edge of the coating will throw off one or more pencils or brushes of light into the air, which visibly incline towards the charging wire of the bottle, and sometimes actually reach it. If I hold the bottle by the coating, and present the knob to the prime conductor, charging it positively (the bottle being in a proper state) a small spark of light first appears upon the edge of the cork in the neck of the bottle, through  
which

which the wire passes; after a few turns of the globe, this spark becomes a fine brush, darting out from the cork, and gradually lengthening, till it forms a beautiful arch, the end of it regularly extending downward, till it reaches the edge of the coating and rests upon it (see fig. 5.). I remember, when I first shewed these experiments to my sincerely respected and worthy friend the late ingenious Mr. FERGUSON, F. R. S. he expressed great satisfaction; and assured me, that he thought them some of the most convincing he had ever seen exhibited for the purpose. If the bottle be dry, it will, in both cases, be discharged spontaneously; but if the uncoated part of the glass be then breathed upon, the appearances may be produced at pleasure. I have lately prepared another bottle for this purpose, the inside of which is coated in the usual manner; but the outside is covered with square pieces of tin-foil about a quarter of an inch broad, and about three-sixteenths of an inch distant from each other; the bottom is compleatly covered with the coating (fig. 4.). If in charging this bottle, the electricity passed absolutely through the glass, it would find a ready conveyance by the coated bottom into the table (and then indeed it could never be charged at all); but the truth is, that this bottle does not become charged till strong flashes of electricity have passed,

diverging in different directions quite round it. If it be discharged by bringing a pointed wire near the wire, or the prime conductor, with which it is in contact, the noise it occasions much resembles the report of a fired cracker; and the uncoated glass between the spots of tin-foil is very brilliantly illuminated. If the bottle discharges itself spontaneously, or be discharged suddenly, by making a regular communication by the rod between the two surfaces of the glass, the whole outside surface seems to be illuminated. To produce these appearances the glass must be thoroughly dry.

#### EXPERIMENT.

A smooth piece of mahogany, two inches square and five inches long, was hollowed into an elliptic groove, about three-quarters of an inch deep, and painted with lamp-black and oil. Into this groove two wires, terminated by brass balls each three-quarters of an inch in diameter, were introduced; the brass balls being placed about one inch and an half from each other: between the brass balls, at an equal distance from each, was placed a ball of the pith of elder, half an inch in diameter, nicely turned in a lathe. The apparatus being thus adjusted, and the circuit completed by a short chain, a bottle, containing forty square inches of coated surface,

was

was many times discharged through it; and whether the bottle was charged positively or negatively, the pith-ball constantly moved in the direction of the fluid, according to Dr. FRANKLIN's hypothesis. This is a delicate experiment; but, as I have perfectly succeeded in it, I thought it proper to give this short account of it. Perhaps if the pith-ball were suspended by a silk string, it might answer the purpose as well; but this I have not tried.

## E X P E R I M E N T.

In melting small wires some inches in length, I have often observed the wire to become red-hot, first at that end in contact with the discharging rod, and the redness has proceeded gradually and regularly towards the coating of the jars or battery; plainly and fully demonstrating the direction of the electric matter in the discharge of the jars or battery, which, for this experiment, were always charged positively. This phenomenon hath also been observed by Mr. BELL, and many times by Mr. NAIRNE.

## E X P E R I M E N T.

Before I quit the subject of the Leyden bottle, I shall mention one experiment more which I have lately made, and which gives a full and compleat answer to a paragraph in Dr. PRIESTLEY's History of Electricity, 2d edit. p. 465. l. 21. It is this: I procured some phials coated with fil-

ver, by burning it into the very substance of the glass, in such a manner that nothing can remove it without injuring the glass together with the metal. Glass thus coated and burnished has certainly a most elegant appearance, has no inequalities or points upon its surface, and charges as high and as readily as when it is coated with tin-foil; such glasses will discharge spontaneously, and one of them, which was very thin, was burst by the explosion; an accident which, by this double annealing, I was in hopes to have prevented, but was sorry to find myself disappointed.

#### OBSERVATIONS ON EXCITED GLASS.

In my remarks on Mr. VOLTA's curious little machine lately presented to the Royal Society, I have observed that the electric matter, being once thoroughly excited and put in action, is not so soon as might be expected reduced again to a quiescent state, especially in bodies so peculiarly adapted to affect each other as these appear to be. As a proof, I introduced the experiments with the looking-glass, crown-glass, and Dutch plates. I also mentioned Dr. PRIESTLEY's observations on the *residuum* of his battery; and in a note to that paper, I added an experiment made by my friend the rev. Mr. HEMMING, F. R. S. who shewed me a small bottle, which then attracted a thread of trial, though it had stood in a cup-



board in his study seventy days from the time he charged it. I also mentioned a singular effect of his cylinder, which will separate the balls of Mr. CANTON's electrometer, at twelve or fourteen inches distance, sometimes a fortnight after using, though the air of the room may have been many times changed, and a variety of methods used to destroy that power in the interval. As the detail is curious, I shall here insert one set of experiments, as I find them registered in a journal, which Mr. HEMMING took the trouble to make for my satisfaction. On May 13 1776, the cylinder was used, and when placed in the cupboard at 10 o'clock A. M. it separated the balls at seven inches distance. The power was then entirely destroyed by breathing on it, and the electricity marked 0. From that time the journal proceeds as follows:

Day.	Hour.	Distance at which the balls diverge.
May 13	11 A. M.	7 inches.
14	8 A. M.	13
Breathed on it once,		9
Ditto four times,		8
Door open till	9 $\frac{1}{2}$ A. M.	5
14	3 P. M.	7
	7 P. M.	6
	10 P. M.	6 $\frac{1}{2}$
		Breathed

Day.	Hour.	Distance at which the balls diverge.
Breathed on it twice,		0 inches
May 14	10 $\frac{1}{2}$ P. M.	6
15	8 P. M.	13 wind N.
Door open ten minutes,		8
	9 P. M.	13
	10 P. M.	8
The power destroyed by flame,		0
16	7 A. M.	14 $\frac{1}{2}$ wind N.
18	8 P. M.	17 wind N.
	11 P. M.	7 $\frac{1}{2}$
Destroyed by flame,		0
20 A fire in the room the whole day.		
	4 P. M.	2
	8 P. M.	1
	10 P. M.	3
21	7 A. M.	9
	9 P. M.	9
Destroyed by flame quite round		0
22	7 A. M.	8 $\frac{1}{2}$
	10 A. M.	11 $\frac{1}{2}$ wind N.
Applied flame quite round the cylinder,		0
	1 P. M.	12 $\frac{1}{2}$

May

# Observations in Electricity.

III

Day.	Hour.	Distance at which the balls diverge.
May 22	4 P. M.	12 $\frac{1}{2}$ inches.
	8 P. M.	{ flame quite round. } 0
	10 $\frac{1}{2}$ P. M.	2

23d, Mr. HEMMING shewed me the experiment, when I saw the balls separate at twelve inches distance from the cylinder. The cause of these phenomena is, no doubt, the excited electricity lodged in the pores of the glass acting upon the vapour in the air of the room, and producing a greater or less effect, as circumstances may contribute to increase or diminish its operation. The cylinder was now used again, which closed this set of observations. Mr. HEMMING has added a meteorological journal for the time; but the particulars of this I did not think it necessary to introduce in the above extract.

## A SECOND SET OF OBSERVATIONS.

Feb. 3, 1777, the cylinder was excited, and from the 5th to the 14th no fire had been made in the study.

Day.	Hour.	Distance at which the balls diverge.
14 <sup>(b)</sup>	3 P. M.	7 inches.
	10 P. M.	0
15	9 A. M.	11

(b) This was the first time, since August or September, that I had observed any cylinder to retain its attractive power longer than twelve hours after being excited, though it was constantly kept in the same place, and, as well as I can observe, under the very same circumstances.

Feb.

Day.	Hour.	Distance at which the balls diverge.
Feb. 15	4 P. M.	8 inches.
	9 P. M.	0
	10 P. M.	0
A large fire in the study the whole day.		
16	9 A. M.	9
	12	9
	8 P. M.	0
	10 P. M.	0
17	9 A. M.	3
	6 P. M.	2
	11 P. M.	0
18	8 $\frac{1}{2}$ A. M.	2
Abfent till 22d,	3 P. M.	8
	6 P. M.	2
	7 P. M.	0
	11 P. M.	0
23	8 A. M.	7
	2 P. M.	2
	5 P. M.	0
	9 P. M.	0
	11 P. M.	0
24	9 A. M.	0
	12	0
	3 P. M.	0

Feb.

# *Observations in Electricity.*

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Day.	Hour.	Distance at which the balls diverge.
Feb. 25	9 A. M.	2 inches.
Absent till 28th,	3 P. M.	2
	9 P. M.	0
Mar. 1	9 A. M.	0
The fire in the study put out at noon.		
	10 P. M.	0
2	9 A. M.	0
	1 P. M.	0
Absent till 8th,	3 P. M.	9 $\frac{1}{2}$
	6 P. M.	4
	8	0
	9 } P. M.	
	10 }	
9	8 A. M.	9
	7	0
	8 } P. M.	
	10 }	
10	8 A. M.	8

The cylinder was now excited again, which closed this set of observations. These changes in the electricity seem very extraordinary, and I think them not easily to be accounted for, as they happened in states of the weather which were totally different. I regret, however, that an accurate and sensible hygrometer was not observed the

whole time; and for such a purpose I should recommend Mr. COVENTRY'S, made with a number of circular pieces of issue-paper, amounting to a certain weight, thoroughly heated and strung on a thread, kept separate from each other by a small glass bead, and suspended on one of the ends of a lever, nicely poised, and turning freely on its axis; the other end serving as an index to a graduated scale, on which it shews the weight of the moisture imbibed at any time by the papers. This hygrometer, from its extreme sensibility, I should choose, I say, to recommend for this purpose, in preference to any other that I have ever seen.

HAVING lately had occasion to shew the experiments with the coated Dutch plates to an excellent electrician (Mr. CAVALLLO) and having charged them as high as I could, and separated them I think rather more expeditiously than usual, I was astonished to find, that the very same plates I have so often mentioned were now charged, the one positively, the other negatively, on both surfaces. I then laid them together, and having made the discharge as usual, I separated them, and found one of the plates negative on both sides, and the other plate positive on one surface, and negative on the other. Here was a new cause of admiration, and I was utterly at a loss to account for it, as the plates had in every instance before

fore uniformly acted as represented in my paper. At length I recollected, that this experiment had been made rather more expeditiously than usual: I therefore repeated it, and having allowed somewhat more time between the removal of the plates from the prime conductor, and the separation of them, in order to examine their electricity, I found on each plate a positive and a negative surface; and having replaced them and made the discharge, I observed that the electricity of all the surfaces was changed. I have mentioned this circumstance, to shew how small a difference in the manner of making an experiment, will make an essential difference also in the result. There is something, however, very singular in this kind of glass, which I believe is owing to its not being properly annealed; for I once met with a plate of it which I found very difficult to charge at all; and when a small quantity of electricity had been forced into it, it dissipated proportionably sooner, without the use of the discharging rod.

In glass, properly annealed, whether in the form of plates or jars, prepared for the Leyden experiment, the dissipation of the electricity is, in some states of the atmosphere, a remarkable, and sometimes (when there is not a fire in the room) a disagreeable circumstance: this effect, however, in the jar itself, may be in a great measure prevented, by having the uncoated part of the glass

neatly covered with the best varnish<sup>(g)</sup>; and I should not omit to observe, that Mr. HEMMING's bottle, which retained its charge so long, was prepared in this manner.

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## P O S T S C R I P T,

*Containing some experiments and observations on Mr. VOLTA's machine, by Mr. TIBERIUS CAVALLO, with remarks by Mr. HENLY.*

Mr. VOLTA's machine, which occasioned several of the preceding enquiries, hath lately been made by Mr. CAVALLO, by coating the glass plate (about six inches in diameter) with sealing-wax. With one excitation of this plate he soon charged a bottle completely, and with that charge pierced three holes in a card, which he hath since shewed me. If, when this machine acted vigorously, he inverted the excited plate, and set the brass plate upon the glass, he produced a contrary electricity, but in a much smaller degree. If when the sealing-wax was strongly excited, so that sparks, two inches long, might be drawn from the brass plate, the excited wax, &c. was placed on an electric stand, and the process continued as usual; the sparks from the brass plate presently dimi-

(g) The varnishing should be several times repeated.

nished,



nished, and in a short time almost totally ceased: this, I think, clearly indicates that the electricity in the lower surface of the glass and the table were mutually affected in the operation, as well as that, in the excited sealing-wax and the brass plate<sup>(b)</sup>. I have seen one of these machines, made by Mr. CAVALLO, act so strongly that, upon separating the brass plate from the sealing-wax, a flash has struck from the brass toward the table, and it has besides given a strong spark upon the knuckle, when held at upwards of an inch distance. If the brass plate, after being raised from the wax, be presented with its edge toward the wax (lightly touching it) and thus drawn over its surface, the electricity of the plate, he observes, will be absorbed by the sealing-wax, clearly shewing the strong negative state in which the excited wax is left on the removal of the brass plate.

The attraction between the plates is also sometimes so strong, that the coated glass has frequently been lifted up by the brass plate from the table; yet in a few days, being carefully placed in a proper repository (in contact with each other) not the least sign of electricity has been

(b) It has been supposed by some gentlemen, that the very same quantity of electricity imparted by the finger to the plate on touching it, was emitted again by the plate on removing it from the electric and presenting it towards the knuckle; and that therefore, in air perfectly dry, this machine would at all times exhibit its phenomena without a fresh excitation of the electric, and thus merit the appellation of a machine for exhibiting perpetual electricity: but the fact above mentioned entirely refutes that supposition.

discoverable on their separation: so far is even this machine from exhibiting perpetual electricity. Indeed, in this particular, it is far exceeded by Mr. GREY's apparatus of the cone of sulphur in the glass, which, on being separated, I have never perceived to fail of exhibiting strong signs of electricity, in every state of the weather. To this apparatus I have lately added the improvements of M. ÆPINAS, and find that they fully answer his report.

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THE following paper contains a set of experiments which may perhaps lead to some curious, useful, and important truths in electricity. They are made with the most simple apparatus, and in the most simple manner; nothing more being requisite for this purpose than a few sticks of sealing-wax (one of them being reserved as a test) to the ends of which the substances to be examined are to be fixed or tied as occasion may require, and Mr. CANTON's electrometer, neatly made and properly insulated. With this small apparatus may almost every article that can be proposed be examined with the utmost facility. The animal, the vegetable, the fossil kingdom, with all the works and combinations of art and manufacture, may afford materials; almost any of which, by a slight friction against woollen cloth or silk, will become

electrified (either positively or negatively, according to the nature of the substance and form of its surface, and the quality and surface of the rubber) sufficiently to separate the balls of the electrometer, so as to determine their electricity in a very satisfactory manner. This, I think, fully confirms an opinion I have long entertained and mentioned in a former paper, *viz.* that the slightest friction of bodies of every kind, in every situation, may disturb the electric matter contained in them, though the effect be imperceptible to us, having no electrometer nice enough to discover it. Here, therefore, is a boundless field for future enquiry; and, to assist those who may be inclined to prosecute it, I shall mention a few general observations and precautions, which I have found exceedingly useful in the course of my own experiments. 1<sup>st</sup>, The air should be dry, and the apparatus clean and warm. 2<sup>dly</sup>, The substances to be tried should be perfectly clean. 3<sup>dly</sup>, When the rubber hath been used once or twice, it should be held near the fire or the flame of a candle, not only to prevent its acquiring moisture, but to take off the electricity left in it by one substance, before another be examined; for it should always be remembered, that whenever a substance is made electrical by friction, the rubber acquires the contrary electricity, and this electricity, if it be not carefully taken off as is above directed, will

will sometimes remain in it so as to confuse and actually mislead in the experiments. 4thly, Some minute substances, as a small leaf, seed, or hair, will not be easily excited in damp weather; these, therefore, as well as the apparatus, should be warmed; for heat, I find, doth always dispose bodies to become electrical. 5thly, The insulating stands, and the sticks of sealing-wax, with which the substances to be examined are connected, should not be rubbed, lest they, by the friction, should be made electrical, and, acting through the substance in contact with them, deceive in the experiment. 6thly, The animal substances, as hair, horn, bone, cartilage, nails, teeth, muscles, &c. become electrified positively, by friction, against woollen cloth or black silk; and the vegetable creation, with very few exceptions, negatively. The metals differ with respect to kinds, form, and surface, and may be differently affected by different rubbers. Lastly, I must not omit to observe that, among vegetables, I find the hot, acrid, pungent, and aromatic substances, as the spices, &c. to be much more easily excited, and stronger in their power, than the cold ones, as the seeds of gourd, melon, or cucumber. Among the herbs, hemlock and parsley are strong: a single leaf of laurel, bay, yew, rosemary, &c. will be found very powerful; but, as I have before observed, this field is indeed immense, and life itself too short

short for a compleat investigation. The experiments prove, however, how universally the electric matter is diffeminated; or, in other words, its existence in all bodies; with what readiness it is excited; and, I think, the constancy of its action (though imperceptible to us) as well as its use and importance, as a principal agent in the greatest, and to mankind the most interesting, operations in nature. I have enclosed a catalogue, exhibiting at one view the articles I have had an opportunity to try, with their kinds of electricity marked against them; hoping this specimen may induce gentlemen of more leisure to pursue the enquiry.

Hair, wool, down, and many other articles, may be made up in the form of little tassels, and in this manner readily fixed upon or tied to the end of an electric for experiment.

The following substances being fixed or tied upon the end of a stick of sealing-wax, and excited by friction against a woollen garment or a piece of soft black silk, became electrified as marked in the columns of the annexed table. The strongest in power are distinguished by the letter s, and the weakest by the letter w.

## M E T A L S.

	Wool.	Silk.
A new guinea; a smooth six pence; a brass ferule; tin, and tin-foil; enamelled copper, s; gilding on leather, s; lead ore; copper ore; iron ore; stream tin;	Neg.	Neg.
Milled lead; copper, s; a polished steel button, s; a new silver ditto; a metal button gilt, s; tutenague ditto, s; iron;		
Lead from a tea-chest, in which there is a mixture of tin, w;	Neg.	Pof.
A gilt button, basket pattern; the junction at the end of a brass ferule;	Pof.	Neg.

## A N I M A L

ANIMAL SUBSTANCES.

Tortoise-shell, w; ivory, s; bone, s; horn; lamb's-tooth; horse's-hoof; deer's-hoof; muscle of the leg of a deer, s; cartilage, s; spur of a young cock; bill, claw, and scale from the leg of a turkey, s; scale of a carp; the *chrysalis* of a moth, recent from the earth, cleansed; *crassamentum* of the human blood exciccated, w; quills; claw of an unboiled lobster; cowrie and several other smooth shells, s; shell of a hen's egg; tail of a small fish; thigh of the elephant beetle; a small beetle, smooth surface; human hair; red and white horse's and bullock's hair, s; hog's bristles, s; wool; silk from the worm, w; oyster-shell, smooth surface;

Wool. Silk.

Pos. Pos.

Mother of pearl, and several other shells;

Neg. Pos.

Muscle and cockle-shells, recent; a recent snail-shell, rough surface; *elitra* of the stag-beetle; oyster-shell, rough surface;

Neg. Neg.

## V E G E T A B L E S.

Rind of chestnut, s; Barcelona nut-shell, s; cashew nut, s; cocoa nut-shell polished; brazil; *lignum vitæ*; black ebony, s; box, w; cane, s; *quinquina*, or Peruvian bark, s; tamarind-stone; coffee-berry roasted, s; nutmeg, s; ginger, s; white pepper, freed from the husk, s; cinnamon, s; cloves, s; mace, s; all-spice, s; capficum, both sides of the pod, s; hemlock, s; a clove of garlic; ditto of eschalot, freed from the husk, s; a green onion, s; rue, s; cork, s; leaves of laurel, bay, yew, holly, rosemary, with their berries, s; parsley, s; leaf of turnip; ditto of Savoy cabbage, s; celery, s; fago, s; thyme, s; carrot; turnip; potatoe; an acorn, s; rind of Seville orange, s; a large Windfor bean, s; a white pea; root of the white lily; snow-drop root; seeds of gourd, melon, cucumber, w; a species of long-moss, w; an apple, s; down of the cotton-rush, w; sea-flag; leaf of the American aloe, s; cotton, w;

Wool. Silk.

Neg. Neg.

Hemp;



Hemp; flax; stalk of the tobacco-leaf;	}	Wool.	Silk.
spike, from the leaf of the American aloe;		Neg.	Pof.
<i>palma-christi</i> nut; horfe-radish;			

A white kidney-bean, smooth surface;	}	Pof.	Pof.
black negro of the same; scarlet of the			
same;			

CORALLINES.

Sea-fan, the horny part, w; rough	}	Neg.	Pof.
coral, w;			

Sponge, w; coral polished, w;	Pof.	Pof.
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SALTS.

Allum, w,	Neg.	Neg.
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<i>Borax</i> ,	}	smooth surfaces;	}	Pof.	Pof.
Nitre purified,					

FOSSIL AND MINERAL SUBSTANCES.

Common pebble-stones of all colours,	}	Neg.	Neg.
s; marble, s; pit-coal, s; black-lead,			
w; jet, s; <i>asbestos</i> ; mineralized ful-			
phur; thunder-bolt stone; <i>cornu-ammo-</i>			
<i>nis</i> ; shark's-tooth; coat of petrification;			

Several smooth native crystals; brown	}	Pof.	Pof.
Iceland ditto; <i>talc</i> , s; Ceylon pebble,			
smooth and transparent; agate, s; corne-			
lian; amethyst, s;			

A specimen

A specimen of *gypsum*,

Wool. Silk.  
Neg. Pof.

#### ARTIFICIAL SUBSTANCES.

Staffordshire ware glazed; China ware, s; Wedgwood's ware glazed, s; whale's fin prepared, w; writing-paper; parch- ment, s; sheep's gut,	}	Pof. Pof.
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Tobacco-pipe, s; Wedgwood's ware unglazed; elastic gum, s; hard under- crust of a leaf; a tallow-candle, w; oiled filk; painted paper, s; silver, burnt into glafs, unburnished; pearl-barley, w; In- dian ink, w; blue vitriol, s,	}	Neg. Neg.
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Dr. LEWIS's glafs porcelain,	Neg. Pof.
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Silver burnt into glafs, burnished, could not be excited either with the woollen or filk. It is supposed that the substances being so intimately incorporated or blended together, the friction at the same time excited both the substances, so as to counteract and destroy the effect of each other.

In these experiments I have been assisted by Mr. CAVALLLO and Mr. ADAMS, who have carefully repeated them in my presence. It may be proper to observe also, that the white pea, a scarlet bean, and the thorn from

the American aloe<sup>(b)</sup>, being rubbed upon new, fine, claret-coloured cloth, became weakly electrified positively.

A lock of black hair from a young colt I have observed to become very weakly electrified negatively, when excited either with wool or silk.

It will be proper to observe, that the rubber of woollen cloth, which I used in the preceding experiments, was a part of the coat or waistcoat which I happened to wear at the time; but being desirous to try the effect of another, I took a piece of fine, new, white flannel, and using that side of it which is free from knap, I perceived a remarkable difference; *viz.* the copper and other buttons, the different stones, shells, China ware, most of the animal substances (hair excepted) and all the vegetable ones, which with the former rubbers were positively, being now negatively electrical; but those which were negative with them, I found to be negative with these also<sup>(i)</sup>. In all the experiments with the flannel, I had

hitherto

(b) All these substances have smooth surfaces.

(i) On this account an ingenious friend of mine proposed the following question, *viz.* Whether, if the electric matter were inherent (as I asserted) in the different substances I examined, the kind of electricity could be changed by the use of different rubbers? I reminded him of Mr. CANTON's experiments with a glass tube, and informed him, that a stick of sealing-wax becomes positively electrified by dipping it in quicksilver, or exciting it with a slip of tin-foil; that a smooth glass tube may be made negative by drawing it cross-wise

over

hitherto warmed the substances, but kept the rubber cold; suspecting that, in some cases, the result might be different from what it is when the rubber is warm and the substance cold: but this, with the effect of cloths of different textures and colours, silks, fattins, velvets, leather dressed in oil, and in allum, &c. used as rubbers, I have not had leisure to determine. A small turnip and a potatoe, which I could not excite at all with either of the rubbers when they and the substances were cold, I excited in a very small degree with the flannel a little warmed; but very strongly when the flannel and the respective articles were, each of them, moderately warm. A sprig of celery acted very powerfully when the flannel only had been previously warmed<sup>(k)</sup>. As in all cases the rubber is affected with an electricity contrary to that of the substance rubbed, it will be sufficient for

over the back of a cat, or by exciting it with a dry, warm rabbit's skin; that a small coated bottle may be charged with a slip of writing-paper, excited by drawing it briskly between the fingers of a dry hand so as to pierce a hole in a card; that the dry leathern cover of a book may be made strongly electrical by the friction of a dry hand, and that its electricity is remarkably shewn by touching it with an insulated button, in the form of the plate to Mr. VOLTA'S machine. He then acknowledged, that such an objection as he had started must certainly be groundless.

(k) A *palma-christi* nut was excited very strongly with the flannel, weakly with my coat, and not all (in a room where there was no fire) with the black silk. I have also to add, that some particular substances, though negatively electrical when heated, become positive when cold, by friction against the very same rubber.

many purposes to use a rubber with a handle of glass, wax, &c. with which the electricity of many fixed bodies, gems that are set in metals, &c. and other articles that it would be improper to divide or remove, may be determined. Such rubbers of different forms have been constructed and satisfactorily employed in a variety of instances by Mr. ERRINGTON and Mr. CAVALLO, who have extended their enquiries far beyond the limits at which I desisted; their collection of animal, vegetable, fossil, and artificial substances, added to my catalogue, amounting to almost one thousand articles.

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## C O N C L U S I O N.

AT the conclusion of the second part of the preceding paper, in my remarks upon the electricity of chocolate, I have observed, that many and great discoveries have been made in this age, respecting the action, influence, and effects of electricity; but it is a question that hath been frequently put to electricians, What is electricity? For my own part, I have generally chosen (perhaps for want of a better answer) to reply by a similar question, *viz.* What is air? or, what is water? For, as these are understood to be fluids distinct from all others, and

distinguished by the names they bear, so have I ever considered electricity as a fluid *sui generis*, and properly characterised by the term electricity, electric fluid, or electric matter; and have always avoided the term electric fire, as conveying a confused idea of actual inflammation, burning, &c.: but I now begin really to doubt, whether another appellation might not be applied with greater propriety; whether electricity may not be considered as a pure, ethereal, elementary fire, inherent in all bodies, intimately connected or blended with an earthy or other base, and apparently, though not actually, remaining in it in a quiescent state, till roused into action by some proper application, as motion, or rather friction, which may, and probably does, collect it in our experiments. (But can motion convey instantaneously that which is not material, but only a quality, a property, an accident, or affection, of matter, through such circuits as those of Dr. WATSON, and produce such astonishing effects at the interruption of those circuits? Besides, in Dr. FRANKLIN'S most curious and decisive experiment of charging the Leyden bottle with its own electricity, the glass undergoes no friction whatsoever; but the electricity inherent in it is simply exhausted from one of its surfaces, and forced round upon the other by the electrical apparatus: the same may be asserted of bodies presented toward a conductor negatively electrified,

electrified, or to the insulated rubber of the electrical machine.) That it may be said to reside in vegetables, and is extracted together with their oil; that in fermentation, effervescence, and putrefaction, it flies off in the phlogistic vapour thence arising (see note 1. at the conclusion of this paper); that in distillation it is disengaged and brought over in an ardent spirit, in which it resides, retaining its original properties in a purer base; that, since by the collision of flint, steel, &c. actual fire is instantaneously produced (as in the instance of the dry axle of a carriage, which, by the friction of the nave against it, soon takes fire) so by the friction of other bodies, which by long perseverance would produce the same effect, this latent fire may be first excited, and its appearances, though unobserved, be those we term electrical. A wind-mill, when it works under the break (as the millers term it when no iron is concerned) soon catches fire (the mill-stones, when no corn is between them, produce the same effect, though the motion be the same in both cases) and many a mill hath been consumed by this means. The method used by the Indians, of producing fire by the friction of two pieces of wood against each other is well known; and in all these cases may not the first effects of the latent fire, thus roused into action, be the production of those very appearances we call electrical? See notes 2. 3. 4. 5. and 6.

This thought, I confess, remained so strongly impressed upon my mind, that I requested some of my friends, who had a better opportunity than myself, to make the trial. For this purpose some pieces of wood were baked in an oven, in order to expel the moisture, and prepare them for the experiment. When they were cooled, a friction was begun, which, as I expected, soon produced electricity; one piece of the wood being excited positively, the other negatively, as I have since myself several times experienced. Had the friction been continued, the production of actual fire might perhaps have been the consequence. May not, therefore, the production of actual fire be the *ultimum* of electricity? or, in other words, electricity the first effect of latent fire thus roused into action; actual fire, the second; and inflammation and dissolution, its third and greatest effort? like fermentation, producing first, wine; secondly, vinegar; lastly, putrefaction. To give some countenance to this supposition, let some of the effects of electricity and fire be placed in a comparative view. First, a small iron wire, held in the flame of a candle till it acquires a white heat, will frequently burst into little balls, flying off in all directions. The same effect is produced by a flint and steel; and in a superior manner, by a strong charge of electricity, or a flash of lightning passing through such

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a small



a small wire; the balls then appearing, on examination, to be little more than the *scorie* of the metal. The effect of electricity, lightning, and fire, in destroying the power of the artificial or natural magnets, is a circumstance that hath been often remarked, and repeatedly published. The effects of electricity, in common with fire, on proof-spirit, gun-powder, *phosphorus*, dry lint, and many other substances, must occur to every gentleman conversant in these experiments; indeed the parallel might be continued much further. But it may be asked, if this be really the fact, should not metals become electrical by friction? I answer, they are readily excited, provided they be first properly insulated; (but if metal be rubbed against metal, the phlogiston or latent fire, if I may be allowed the expression, is so nearly proportioned in the two metals, that the equilibrium is restored as soon as destroyed, from the very nature of the base, which is the most perfect conductor we are acquainted with) to illustrate this, let it be remembered, that though the hydrostatic paradox may be readily explained, yet the fluid must be confined in a proper vessel; and though the weight, the spring, and the compressibility of the air, be easily demonstrable, a suitable apparatus must necessarily be employed for each purpose.

It

It is a question by no means decided, how the clouds become electrified? But if we suppose the electric matter to be a pure, ethereal, elementary fire, resident in all bodies; that the great process of vegetation is carried on by means of this subtil, active, volatile, and pervading element; that it is continually exhaling from all the vegetable tribe; that as evaporation is a remarkable agent in the cooling of heated substances, that is, a good conductor of their fire, as I am well assured it is of electricity; may we not conclude, that this is one great cause of the clouds becoming at times furcharged with this fluid? The great effect of electricity in promoting vegetation, hath been fully proved by Dr. DE MAIMBRAY, the abbé NOLLET, Mr. JALLABERT, and other gentlemen, and was very remarkable in that year when the fatal earthquake happened at Lisbon. Dr. STUKELEY's observations on the frequent appearances of fire-balls, coruscations, and *aurora boreales*, at this time (which I well remember) deserve to be particularly noticed; and it is generally remarked, that thunder-storms are preceded by a continuance of hot weather, and that a moderate temperature immediately succeeds the storm. The remarks and observations of the worthy Dr. HALES on this subject seem also to merit peculiar attention. Further, as the rays of the sun, concentrated by a powerful burning

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ing mirror, will produce a fusion of metals, and instantly reduce a number of substances presented to the focus to a *calx*, as the same effect is in many cases produced by a stroke of lightning; and as the colours of the electric and solar light are equally divisible by the prism; may not these also bear some kind of relation to each other<sup>(1)</sup>? Upon the whole, is there not an high degree of probability in the supposition, that light, fire, phlogiston, and electricity, are only different modifications of one and the same principle? See notes 7. 8. and 9. A similarity in several of the phenomena of electricity and magnetism hath been long since pointed out by Dr. PRICE, from M. *ÆPINAS*; and the effect of heat on both admirably displayed by Mr. CANTON. Of all the substances I have yet examined, the most difficult to excite, I observed to be a fine, smooth, unarm'd load-stone, and a piece of black lead; these seemed to bid defiance to all my rubbers: at length, however, with a piece of new flannel they were both excited, in a very small degree, negatively. In short, I have not yet met with a single article (on which the experiment could be tried) that I could not, with one or other of my rubbers, make in

(1) Many other particulars might be adduced in this place; but they are purposely omitted, this paper being already extended far beyond the limits originally intended by the author.

some degree electrical. The laws by which all these fluids are governed, and what constitutes the precise difference between them, may yet, perhaps, by some fortunate philosopher, by a train of just reflexion, and a set of happily contrived and well-conducted experiments, be much farther elucidated. Lastly, I do not speak of these things as facts of which I am absolutely convinced; but earnestly wish to recommend them to the serious consideration of future enquirers. From what hath been said, however, I apprehend it will scarcely be doubted, that electricity, whatever it be (as I have often remarked) is one of the greatest and most important agents in the operations of Nature; that the effects of lightning, therefore, are but as discords in her harmony; and, though singly considered, they may appear unpleasing notes, yet perhaps may be necessary to fill up and compleat her grand and general chorus.

#### NOTES ON THE CONCLUSION.

I. I am just informed by Mr. ADAMS, that Mr. CLARKE, an ingenious gentleman from Ireland, hath lately proved, to the satisfaction of some of the ablest chemists there, that the variety of airs produced by different gentlemen  
in

in their pneumatical researches (that produced from the *calces* of metals perhaps excepted) are only phlogistic vapours arising from, and partaking of, the qualities of the substances from which they are disengaged.

“ The vapour of fermentation is much more subtle than common air, it passes through bodies which would be impenetrable obstacles to the latter.

“ Mr. DE SMETH was not able to retain it by the aid of lutes: a moistened bladder, tied over the mouth of a vessel which contained some fermenting matter, was not at all inflated during the height of fermentation.

“ Dr. PRIESTLEY has observed, that the fixed air from fermenting beer combines easily with the vapour of water, as also with the smoke of rosin, sulphur, and other electrical substances.

“ If it were permitted me to indulge in conjectures, I should say that some experiments induce me to believe, that every elastic fluid results from the combination of some solid or fluid body with the inflammable principle, or perhaps even with the matter of pure fire; and that on this combination the state of elasticity depends.” See HENRY’s translation of M. LAVOISIER’s *Essays*, physical and chemical.

Mr. LANE, in his curious and most important experiment of dissolving iron in water impregnated with fixed

air, observed, that after the water so impregnated had been passed through a close filtering paper, it was rendered quite transparent, the iron being in perfect solution. This clear liquor he endeavoured to preserve in its transparent state, by using every means that then occurred to him to retain the elastic vapour, but without success, for in a few hours the transparency diminished: afterwards the liquor became opaque, and deposited the iron that had been dissolved in it.

2. Several gentlemen have observed, that in working their electrical machines with great velocity, as heat was produced by the friction, the electricity was proportionably lessened.

3. Mr. ERRINGTON, a gentleman who often recreates himself with mechanical operations, frequently observed, that after he had been for some time briskly working his drill, the string of it became strongly electrical.

4. Mr. CAVALLO, who sometimes amuses himself with the violin, having played a few sprightly airs, examined at my request the hairs of the bow, and the strings of the instrument, and found by his electrometer that both of them were electrical; the former in a *plus*, the latter in a *minus* state. In this case, the rosin contributes to

the electricity. Perhaps a tenor or bass-viol might produce the effect in a greater degree.

5. Mr. CAVALLO likewise informs me, that taking two pieces of broken China ware, he struck the edges of them briskly together, and produced sparks of fire, but no electricity. He then rubbed the broader surfaces gently together, and produced a strong electricity; positive in one piece, negative in the other. This experiment I have several times repeated to my entire satisfaction.

6. I have myself observed, that two glass tubes, rubbed briskly together, produce a vivid purple light and strong phosphoreal smell, but no attraction or repulsion; but two pieces of plate glass, each two inches long and one inch broad, warmed and rubbed gently against each other, produce electricity, negative in one piece, positive in the other. Both glass and amber I have also made electrical by blowing upon them (previously warmed) with a pair of bellows.

7. Platina, in the purest state to which it could be reduced by chemistry, and on which Dr. LEWIS informed me that the strongest fires he could raise had no further effect, I have been able to fuse in a small degree, by a strong charge of electricity. *Phil. Transf. vol. LXIV. p. 416.*

8. Since the learned and accurate F. BECCARIA published the account of his curious experiment of revivifying the *calces* of metals by electricity, it hath been repeated with perfect success by several other gentlemen.

9. With respect to earthquakes, upon this hypothesis Dr. STUKELEY's and the rev. Mr. MITCHEL's ingenious theory may both be near to truth, as the difference between them will consist more in words than in facts. See a most curious and astonishing effect of evaporation produced by electricity in Dr. FRANKLIN's Experiments and Observations, first edit. p. 415. Perhaps it may not be improper to mention in this place the following experiment, which I made long since myself. A pretty large wine-glass being nearly filled with water, two wires, terminated by small brass balls, were hung opposite to each other upon the brim of the glass, so as to let the balls descend to about half the depth of the water. The communication being then completed by a chain, a jar containing three square feet of coated surface, was discharged through it. The consequence was, the stem of the glass was broken in two places; the bowl was shivered perhaps into a thousand pieces, and scattered with the water in all directions: part of it flew into my face, and so much upon the apparatus, that I remember it put an end to my experiments for that time. I had neglected to cover the glass, being desirous to see the effect



effect of the charge passing through the water; not suspecting the danger of the electricity evaporating part of it, and exploding with such violence as might have been attended with very disagreeable consequences.

10. That water-spouts are really occasioned by electricity I have long suspected, from several circumstances; but Mr. GEORGE FORSTER, F. R. S. in his curious remarks and circumstantial description of one of these phenomena (*Voyage round the World*, vol. I. p. 191.) seems to have confirmed this matter beyond a doubt: the form of the column, the hail-stones which fell at the time, and the flash of lightning which appeared at the disjunction of the tube, are, I apprehend, as complete proofs as can be given, or as the case can admit or require.

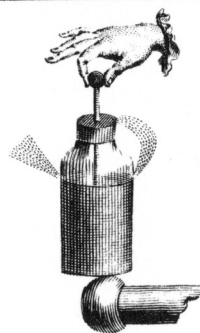
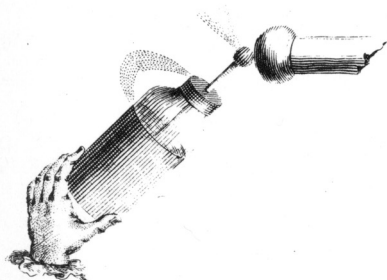
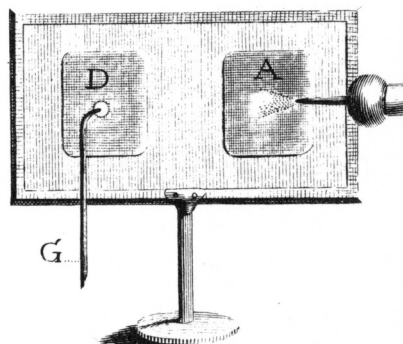
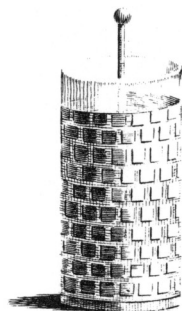
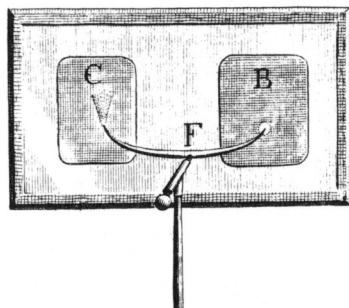
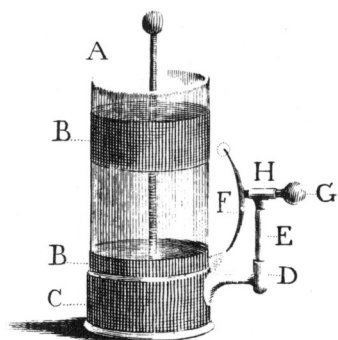
11. Some gentlemen have supposed, that the electric matter is the cause of the cohesion of the particles of bodies. If the electric matter be as I suspect, and my experiments and the foregoing notes seem to prove, a real elementary fire inherent in all bodies, that opinion may probably be well-founded; and perhaps the soldering of metals and the cementation of iron by fire may be considered as strong proofs of the truth of their hypothesis.

12. Dr. PRIESTLEY observes (*Experiments and Observations on Air*, vol. I. p. 280.) That it is probable, that elec-

tric light comes from the electric matter itself; that this being a modification of phlogiston, it is probable that *all light* is a modification of phlogiston also; and that, prior to his deductions from electrical phenomena, it was pretty evident that light and phlogiston are the same thing in different forms or states. Dr. PRIESTLEY's third volume on the same subject was not published till the last sheet of my paper had been composed, and a proof struck off. In the appendix to that volume I find so curious an article in a letter from signor VOLTA to the Doctor, that I shall take the liberty to transcribe a part of it, as a very important addition; *viz.* " I fire inflammable air  
" by the simple electric spark, even when the electricity  
" is very moderate, which explains the *ignes fatui*, pro-  
" vided they consist of inflammable air issuing from  
" marshy ground by the help of the electricity of fogs  
" and by falling-stars, which are very probably thought  
" to have an electrical origin.

" I do not know whether you have ever tried the effect  
" of the Bolognian phosphorus on air. It phlogisticates it  
" in the highest degree, and the diminution it occasions  
" takes place very quickly, and is altogether surprising;  
" but for this purpose the phosphorus must be good,  
" and the weather not too cold."

Since



Since the preceding papers were presented to the Royal Society, I have seen and heard of such a number of curious remarks, observations, and discoveries on light, fire, phlogiston, and electricity, which tend to illustrate and confirm the opinions I have advanced, that I would beg leave to add, that, had I seen or known of several of those excellent pieces in time, I should certainly have availed myself of such important labours, and have spoken of the subjects above-mentioned with a greater degree of confidence. The authors I allude to are, BOERHAAVE on Fire; STAHL on Phlogiston; Dr. PEMBERTON on Fire; Dr. HIGGINS on Light; the celebrated MACQUER, particularly in his Memoir on Phlogiston, in the abbé ROZIER's Journal for Nov. 1776; a Memoir by Mr. OPOIX on Phlogiston and Light; Mr. ACHARD's Electrical Experiments on the Ice of distilled Water, frozen in a degree of cold exceeding what we ever experience in this country; with plates of which ice he not only performed the Leyden experiment, but even excited it by friction like glass (see the Abbé ROZIER's Journal for Nov. 1776); and lastly, M. KOESTLIN's curious and most valuable experiments on the influence of electricity, in the production and support of animal and vegetable life, particularly his discovery that vegetation was actually retarded by electrifying his feeds negatively.

